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Reid et al.

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(54) **POWER SYSTEM FOR GROUND-BASED MACHINES**

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H01F 38/14 (2006.01)

(52) **U.S. Cl.**
CPC ***H01F 38/14*** (2013.01)

(58) **Field of Classification Search**
CPC H01F 38/14
See application file for complete search history.

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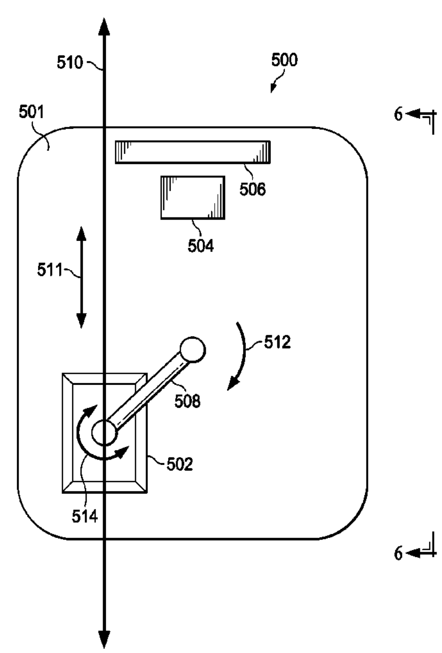
(57) **ABSTRACT**

A method for distributing energy to a group of ground-based machines. The energy is supplied to the group of ground-based machines through a pattern of inductive power transfer lines physically associated with a ground in a work area. Operations are performed with the group of ground-based machines in the work area. The group of ground-based machines moves in the work area without following a path based on the inductive power transfer lines.

18 Claims, 12 Drawing Sheets



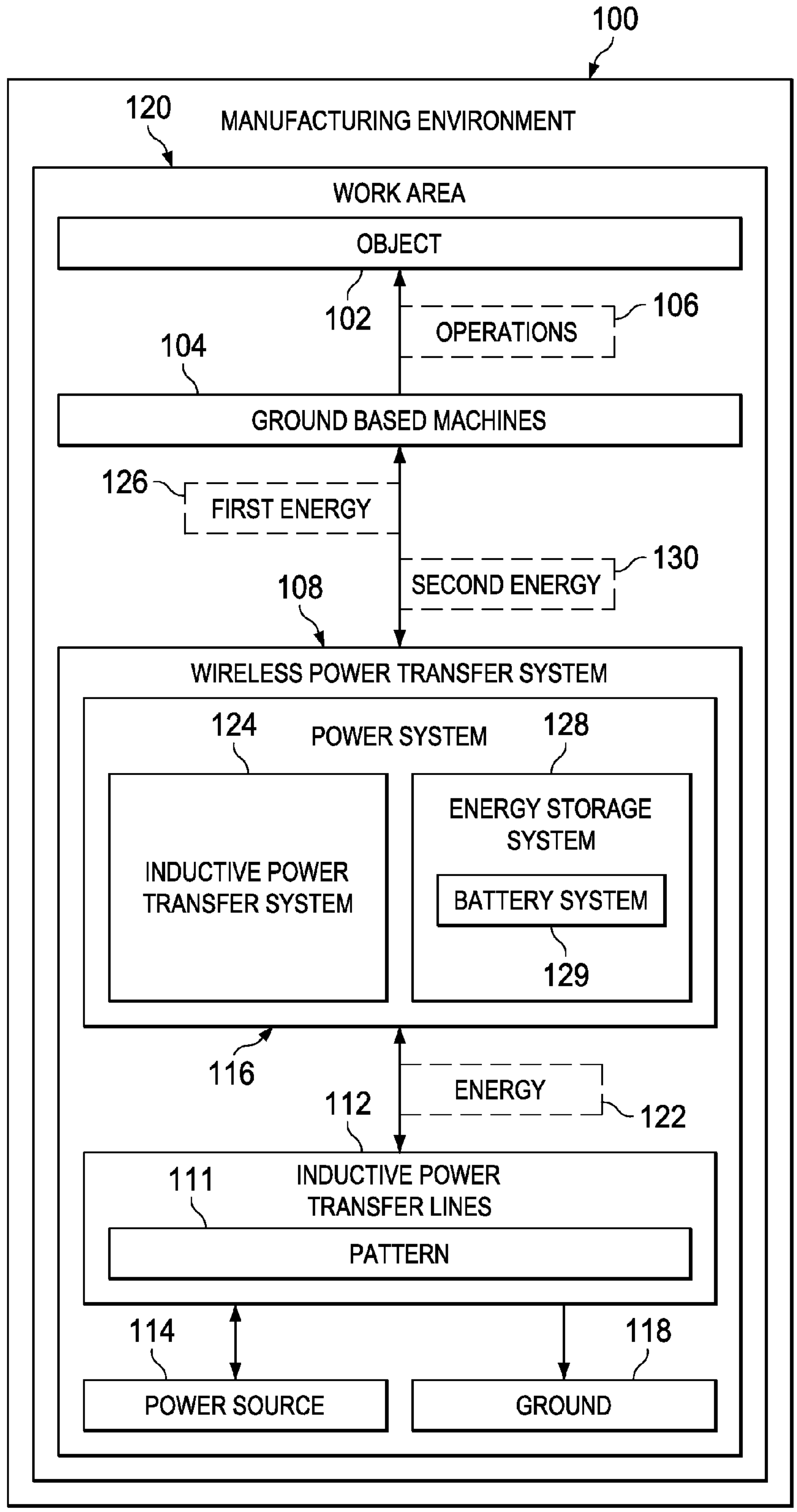

100
120
MANUFACTURING ENVIRONMENT
WORK AREA
OBJECT
102
OPERATIONS
106
104
GROUND BASED MACHINES
126
FIRST ENERGY
SECOND ENERGY
130
108
WIRELESS POWER TRANSFER SYSTEM
124
POWER SYSTEM
128
INDUCTIVE POWER TRANSFER SYSTEM
ENERGY STORAGE SYSTEM
BATTERY SYSTEM
129
116
ENERGY
122
112
111
INDUCTIVE POWER TRANSFER LINES
PATTERN
114
118
POWER SOURCE
GROUND

FIG. 1

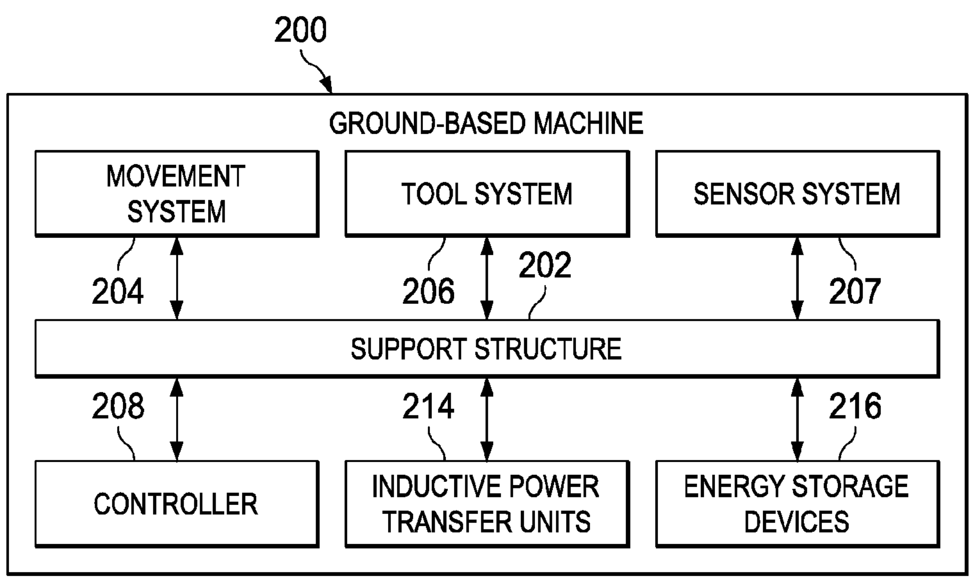

200
GROUND-BASED MACHINE
MOVEMENT SYSTEM
TOOL SYSTEM
SENSOR SYSTEM
204
206
202
207
SUPPORT STRUCTURE
208
214
216
CONTROLLER
INDUCTIVE POWER TRANSFER UNITS
ENERGY STORAGE DEVICES

FIG. 2

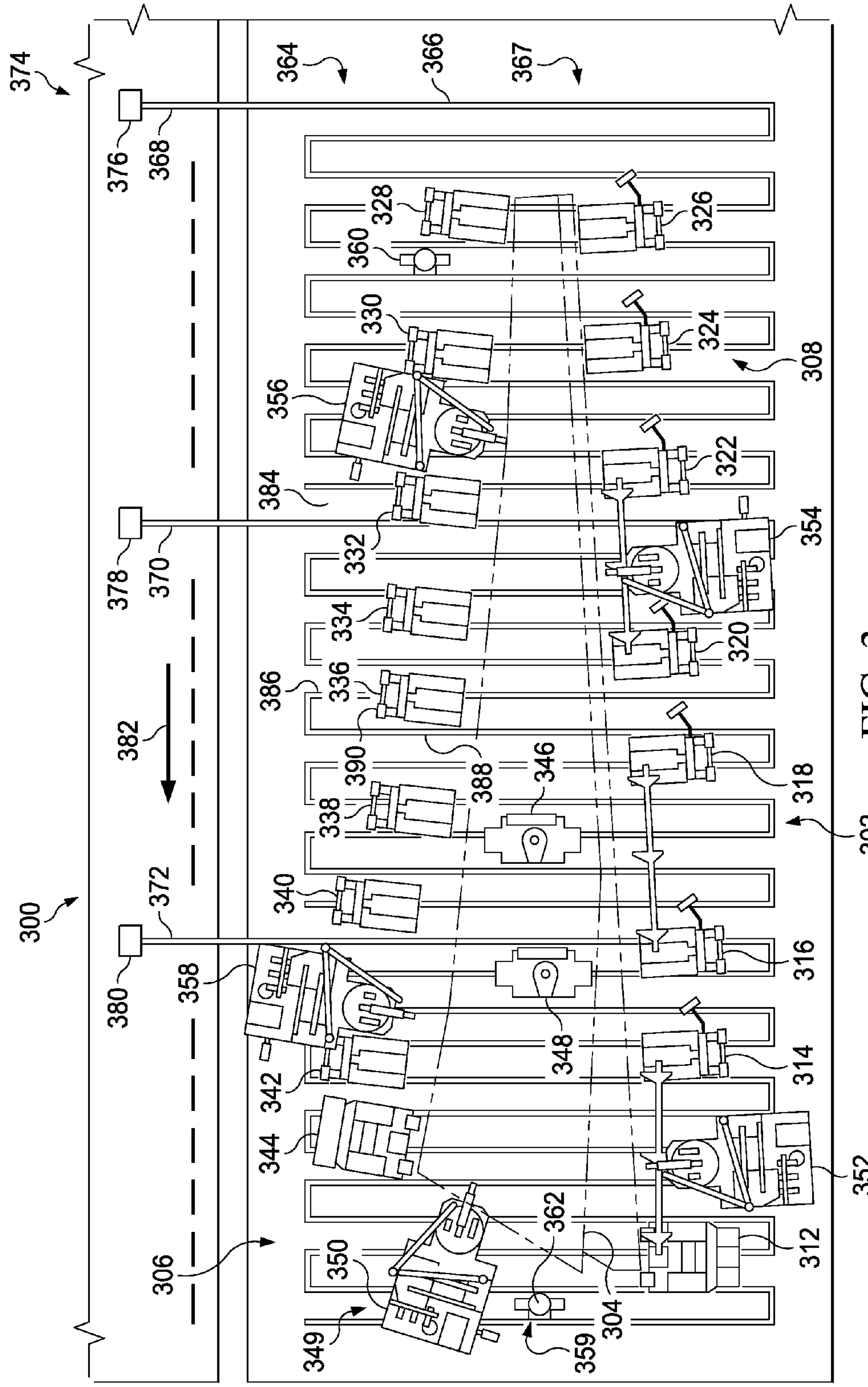

300
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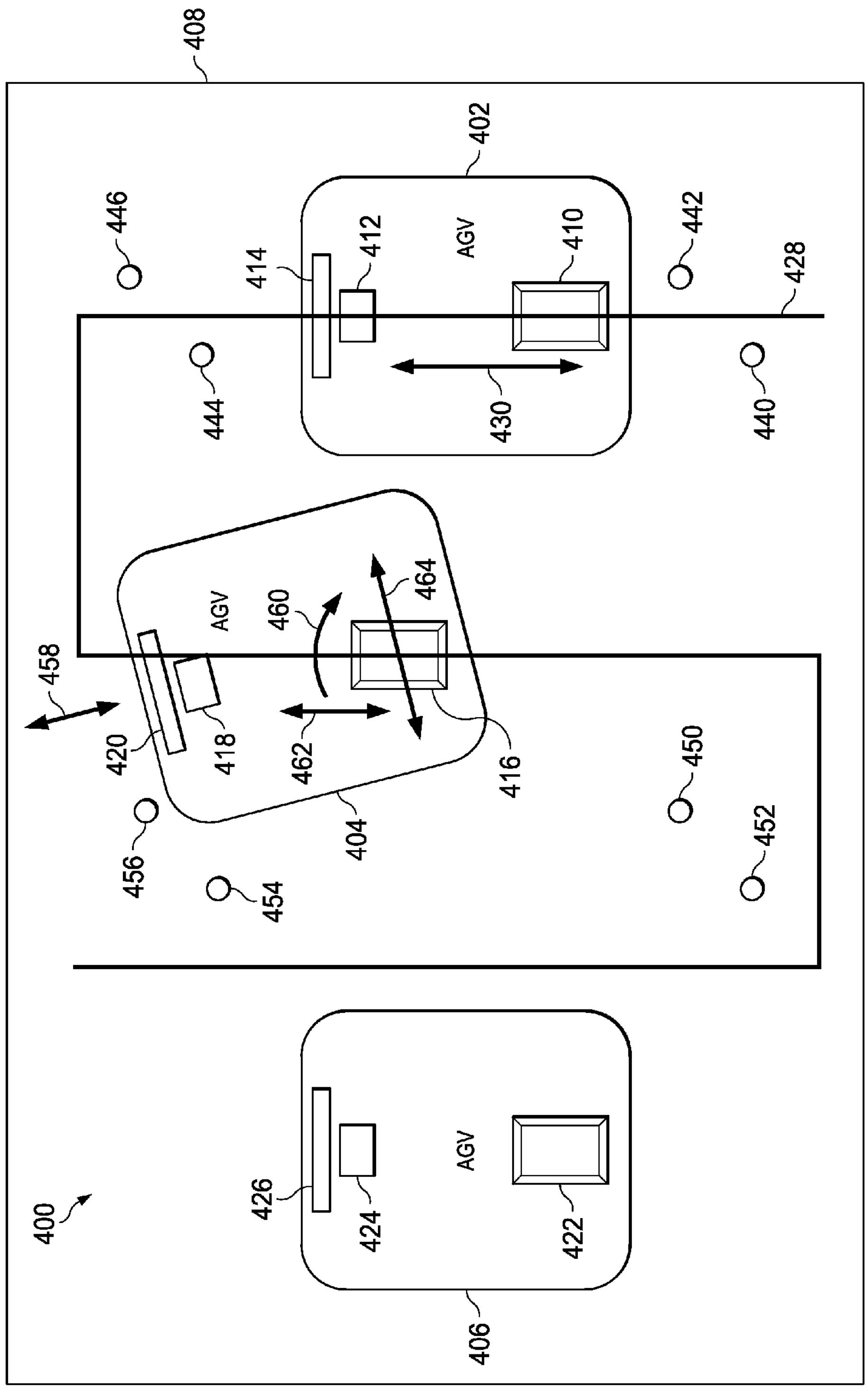
FIG. 3


408
402
AGV
446
412
410
442
414
428
444
430
440
AGV
460
464
458
420
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462
416
450
456
404
452
454
AGV
426
400
424
422
406

FIG. 4

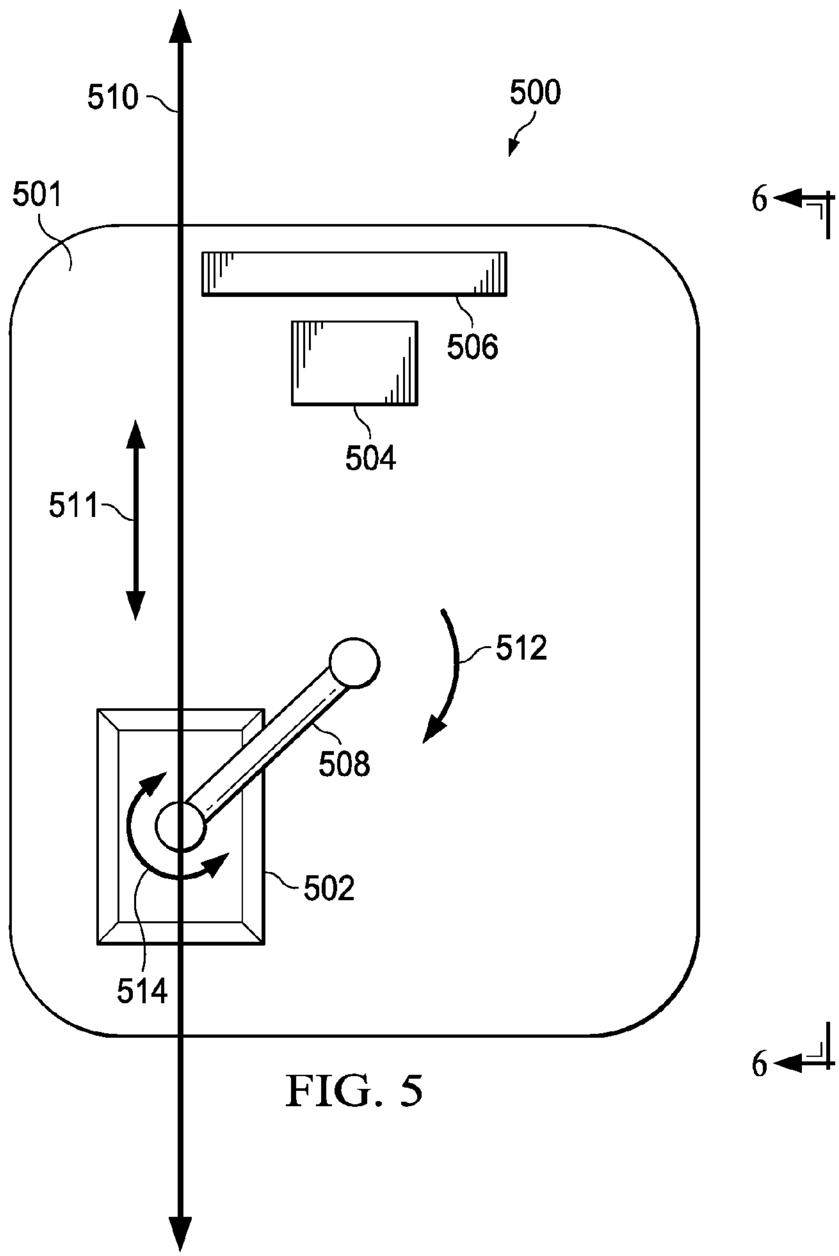


FIG. 5

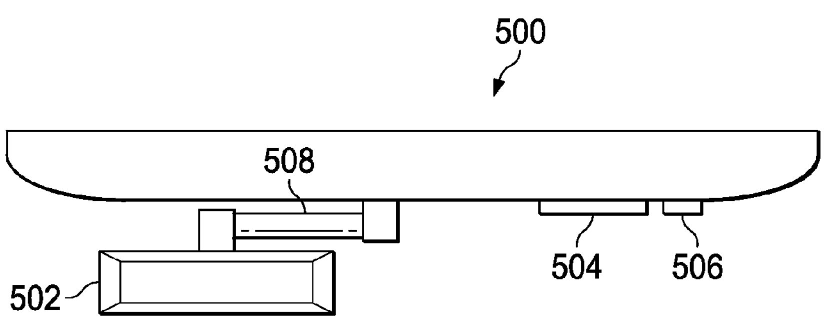
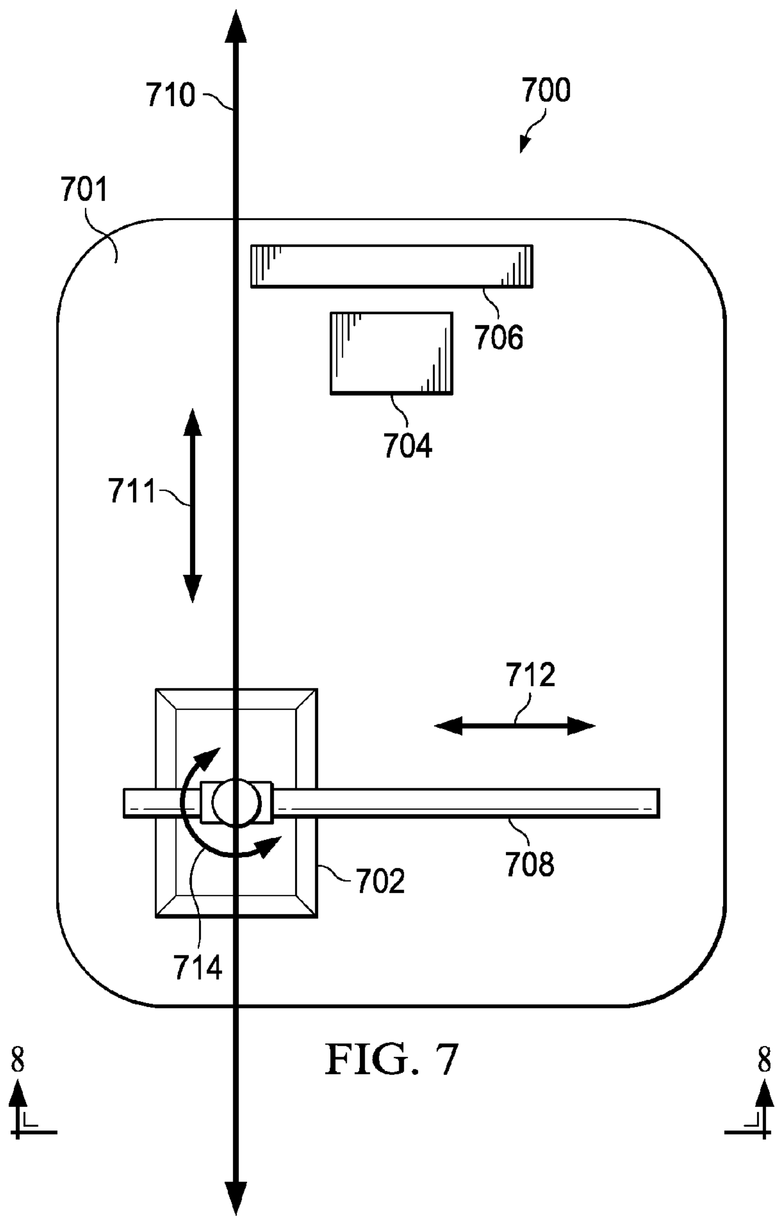
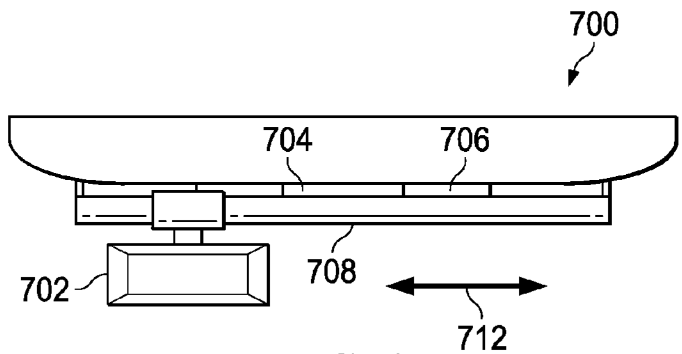


FIG. 6



710
700
701
706
704
711
712
708
702
714
8
8

FIG. 7



700
704
706
702
708
712

FIG. 8

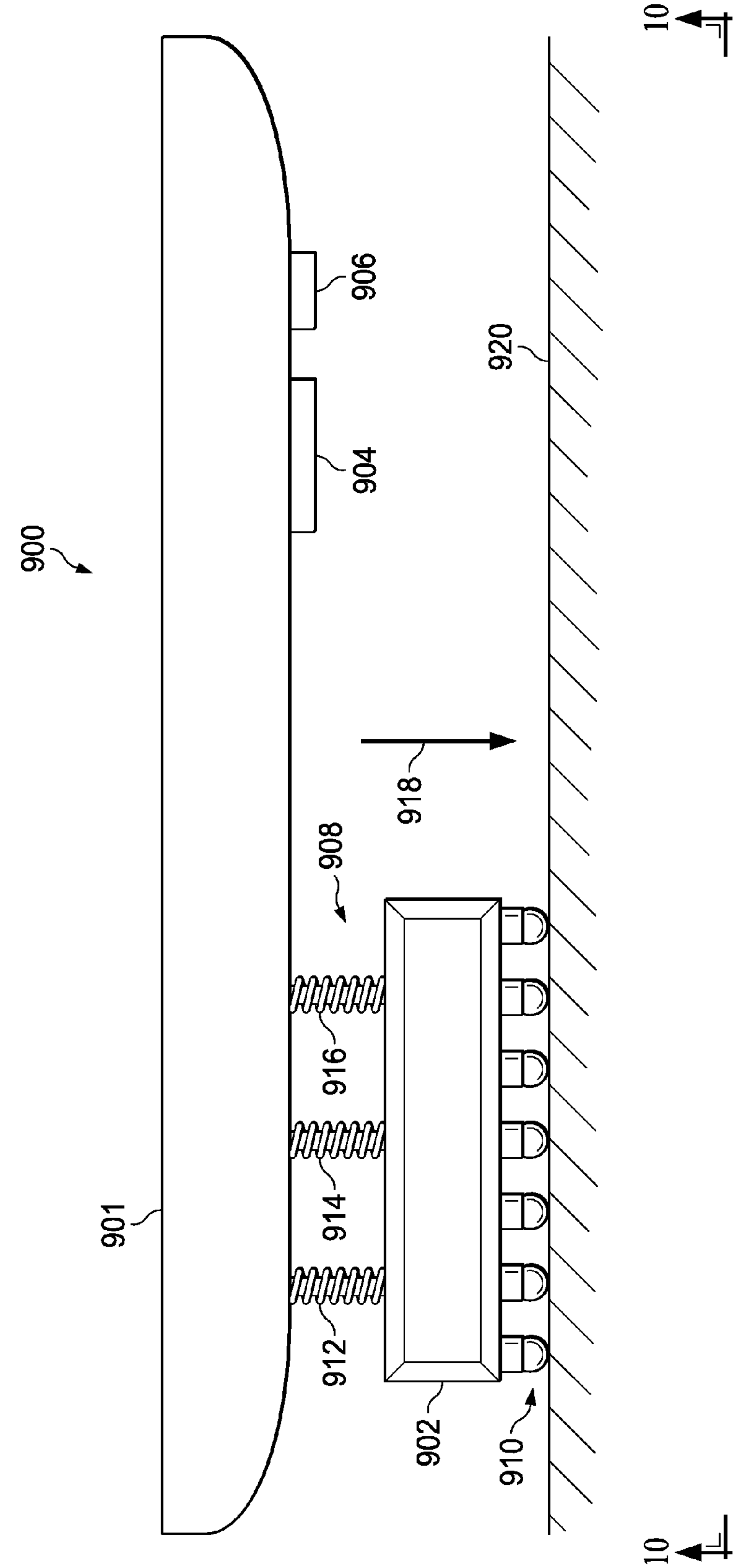


FIG. 9

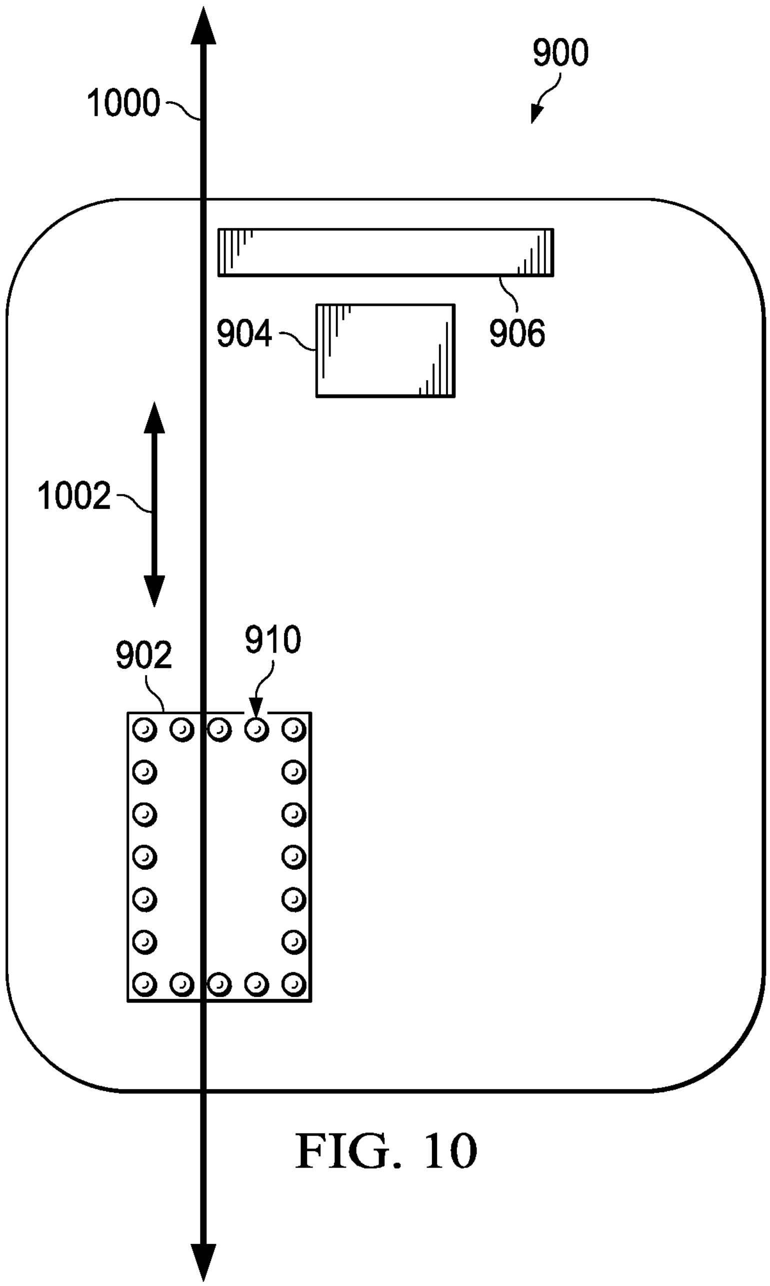


FIG. 10

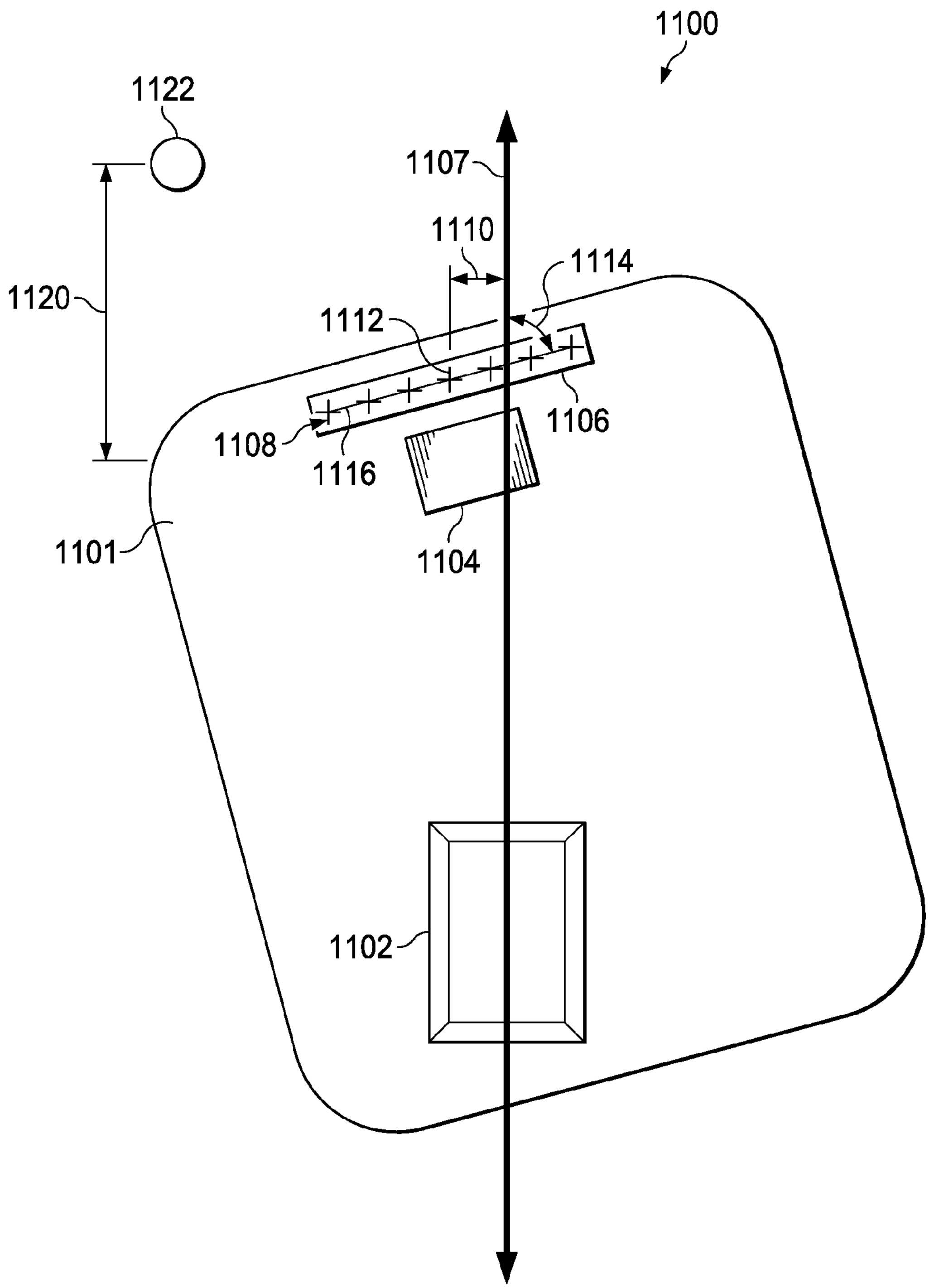

1100
1122
1107
1110
1114
1120
1112
1106
1108
1116
1104
1101
1102

FIG. 11

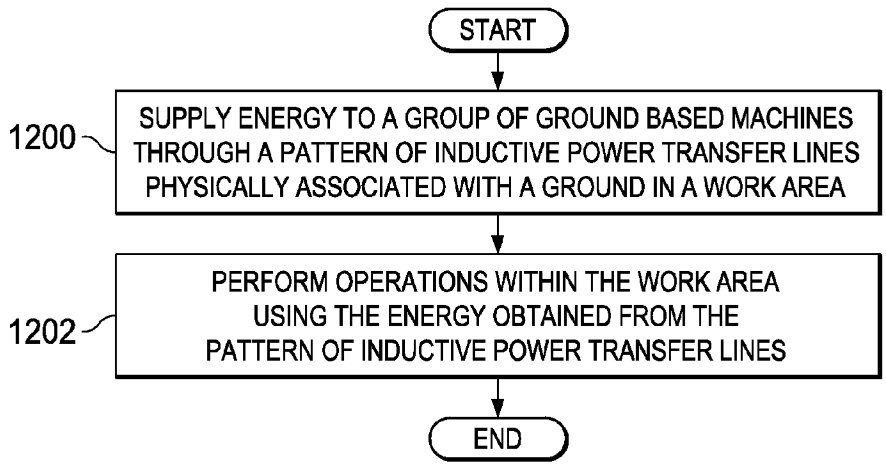

START
1200
SUPPLY ENERGY TO A GROUP OF GROUND BASED MACHINES THROUGH A PATTERN OF INDUCTIVE POWER TRANSFER LINES PHYSICALLY ASSOCIATED WITH A GROUND IN A WORK AREA
1202
PERFORM OPERATIONS WITHIN THE WORK AREA USING THE ENERGY OBTAINED FROM THE PATTERN OF INDUCTIVE POWER TRANSFER LINES
END

FIG. 12

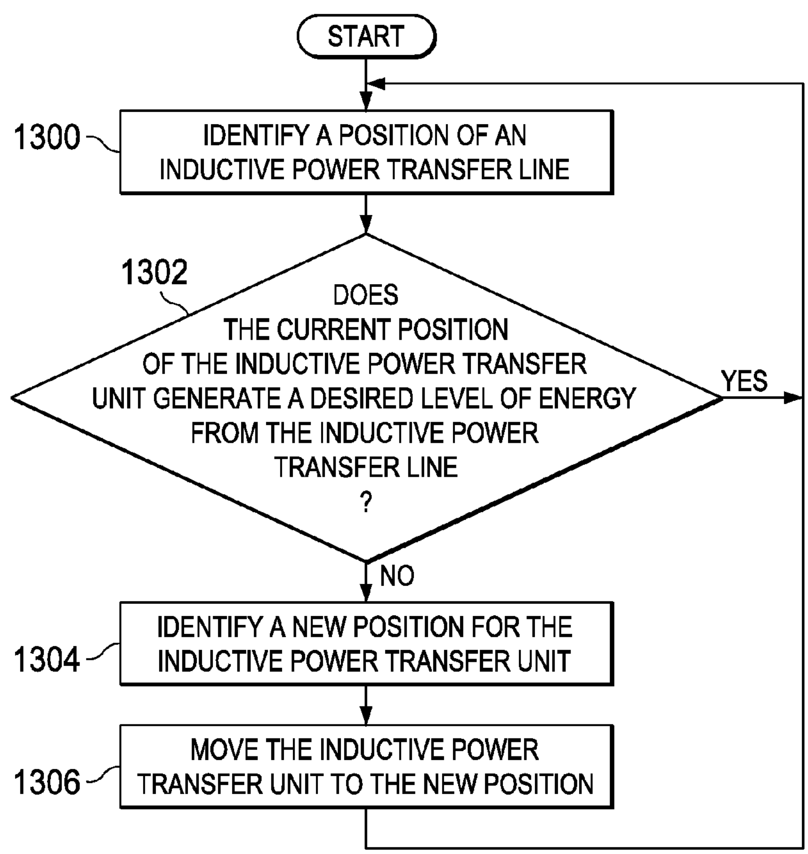

START
1300
IDENTIFY A POSITION OF AN INDUCTIVE POWER TRANSFER LINE
1302
DOES THE CURRENT POSITION OF THE INDUCTIVE POWER TRANSFER UNIT GENERATE A DESIRED LEVEL OF ENERGY FROM THE INDUCTIVE POWER TRANSFER LINE ?
YES
NO
1304
IDENTIFY A NEW POSITION FOR THE INDUCTIVE POWER TRANSFER UNIT
1306
MOVE THE INDUCTIVE POWER TRANSFER UNIT TO THE NEW POSITION

FIG. 13

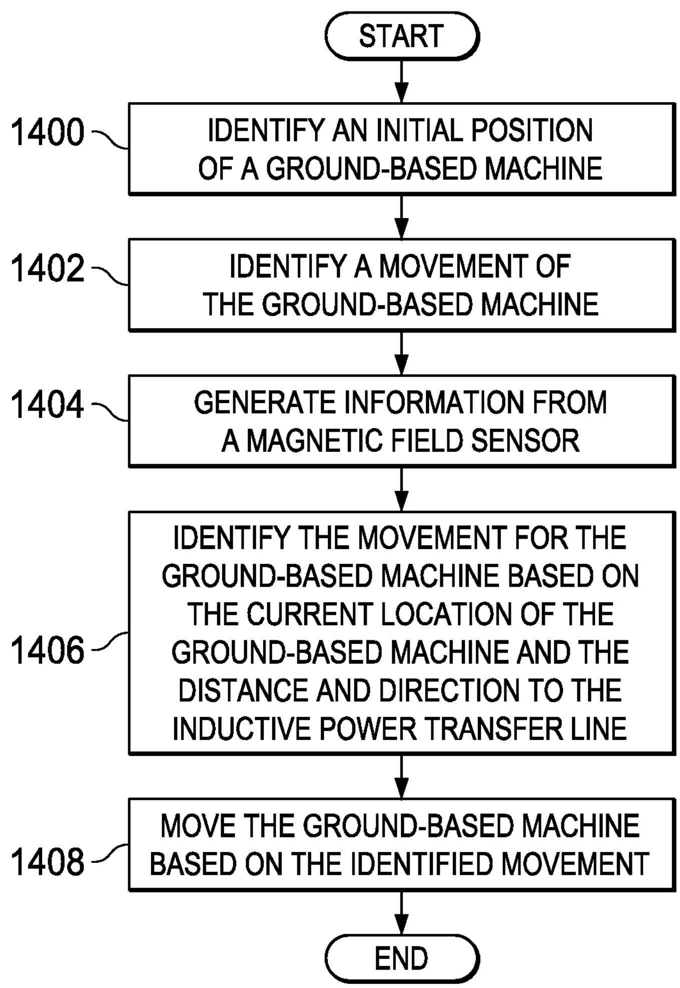

START
1400
IDENTIFY AN INITIAL POSITION OF A GROUND-BASED MACHINE
1402
IDENTIFY A MOVEMENT OF THE GROUND-BASED MACHINE
1404
GENERATE INFORMATION FROM A MAGNETIC FIELD SENSOR
1406
IDENTIFY THE MOVEMENT FOR THE GROUND-BASED MACHINE BASED ON THE CURRENT LOCATION OF THE GROUND-BASED MACHINE AND THE DISTANCE AND DIRECTION TO THE INDUCTIVE POWER TRANSFER LINE
1408
MOVE THE GROUND-BASED MACHINE BASED ON THE IDENTIFIED MOVEMENT
END

FIG. 14

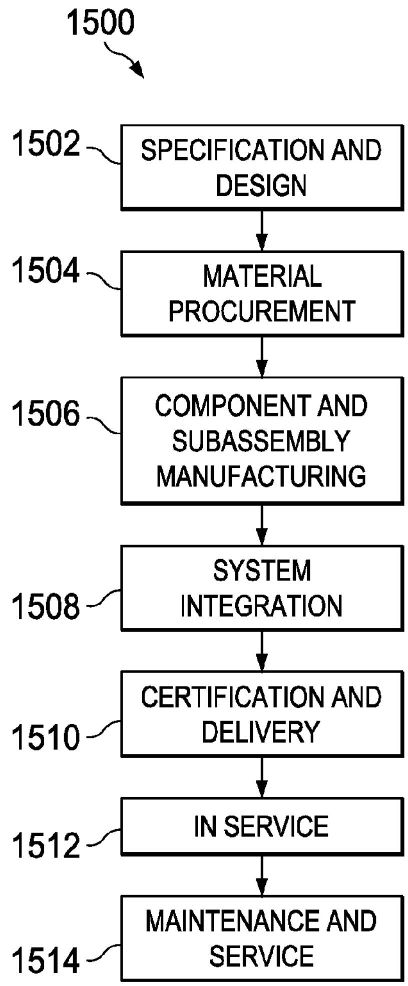

1500
1502
SPECIFICATION AND DESIGN
1504
MATERIAL PROCUREMENT
1506
COMPONENT AND SUBASSEMBLY MANUFACTURING
SYSTEM INTEGRATION
1508
CERTIFICATION AND DELIVERY
1510
IN SERVICE
1512
MAINTENANCE AND SERVICE
1514

FIG. 15

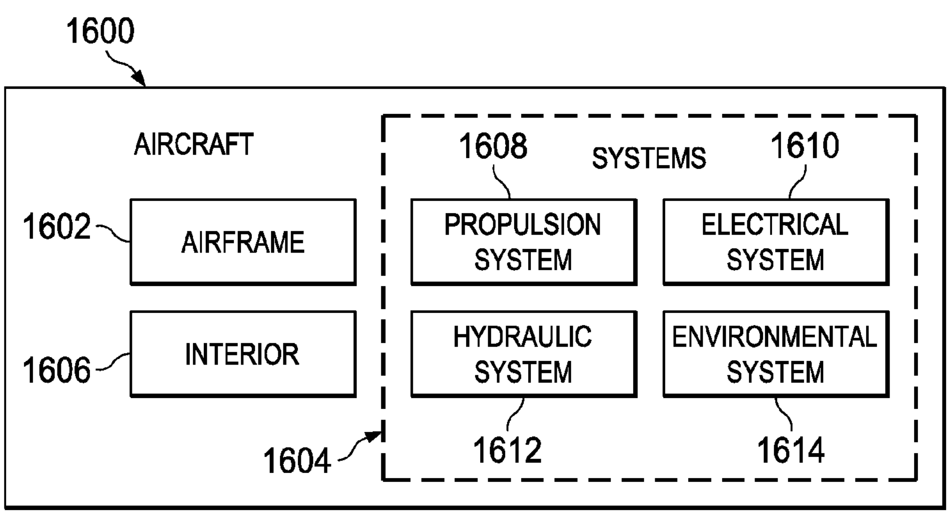

1600
AIRCRAFT
1608
SYSTEMS
1610
1602
AIRFRAME
PROPULSION SYSTEM
ELECTRICAL SYSTEM
HYDRAULIC SYSTEM
ENVIRONMENTAL SYSTEM
1606
INTERIOR
1604
1612
1614

FIG. 16

POWER SYSTEM FOR GROUND-BASED MACHINES

BACKGROUND INFORMATION

1. Field

The present disclosure relates generally to manufacturing and, in particular, to manufacturing objects using ground-based machines. More particularly, the present disclosure relates to a method and apparatus for providing power to ground-based machines.

2. Background

In manufacturing products, an assembly line may be used in a manner where parts are added to form the product in a sequential manner to create a finished product more quickly. Human operators and robotic equipment may be positioned along the assembly line to perform the assembly of the product.

With ground-based machines, such as robotic equipment, power cables may be connected to the robotic equipment to provide power for performing operations in manufacturing products. Often times, these power cables may be grouped using large umbilical cords. The umbilical cords, however, take up room and may become tangled when robotic equipment is moved around. Additionally, movement of equipment may cause inconsistencies in the umbilical cords such that the umbilical cords do not provide a desired amount of power and may require maintenance.

Inductive power transfer systems may be used to remove the need for power cords for robotic equipment and other ground-based machines that may be used to manufacture products. Many of the currently available inductive power transfer systems are designed for use on assembly lines such as those used to manufacture products, such as automobiles. Robotic equipment may be positioned along the assembly line to perform operations.

Changes in the product or manufacturing process may result in the repositioning of robotic equipment along the assembly line. In some cases, the robotic equipment may move some distance along the assembly line in performing operations to manufacture the product. This type of inductive power transfer system, however, may not provide a desired amount of flexibility for manufacturing products that may not be on a traditional assembly line system.

Therefore, it would be desirable to have a method and apparatus that takes into account at least some of the issues discussed above, as well as other possible issues.

SUMMARY

In one illustrative embodiment, an apparatus comprises a group of ground-based machines and a power system. The group of ground-based machines is configured to perform operations in a work area having a pattern of inductive power transfer lines physically associated with a ground in the work area. The power system is configured to obtain energy for the group of ground-based machines from the pattern of inductive power transfer lines such that the group of ground-based machines move in the work area without following a path based on the inductive power transfer lines.

In another illustrative embodiment, a wireless power transfer system comprises a power source and a pattern of inductive power transfer lines physically associated with a ground in a work area and connected to the power source. The power source is configured to generate energy. The pattern of inductive power transfer lines is configured for a group of ground-based machines to move in the work area without following a path based on the inductive power transfer lines.

In yet another illustrative embodiment, a method for distributing energy to a group of ground-based machines is presented. The energy is supplied to the group of ground-based machines through a pattern of inductive power transfer lines physically associated with a ground in a work area. Operations are performed with the group of ground-based machines in the work area. The group of ground-based machines moves in the work area without following a path based on the inductive power transfer lines.

The features and functions can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives and features thereof, will best be understood by reference to the following detailed description of an illustrative embodiment of the present disclosure when read in conjunction with the accompanying drawings, wherein:

FIG. **1** is an illustration of a block diagram of a manufacturing environment in accordance with an illustrative embodiment;

FIG. **2** is an illustration of a block diagram of a ground-based machine in accordance with an illustrative embodiment;

FIG. **3** is an illustration of a manufacturing environment in accordance with an illustrative embodiment;

FIG. **4** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **5** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **6** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **7** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **8** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **9** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **10** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **11** is an illustration of a ground-based machine with an inductive power transfer unit in accordance with an illustrative embodiment;

FIG. **12** is an illustration of a flowchart of a process for distributing energy to ground-based machines in accordance with an illustrative embodiment;

FIG. **13** is an illustration of a flowchart of a process for transferring power from an inductive power transfer line to a ground-based machine in accordance with an illustrative embodiment;

FIG. **14** is an illustration of a flowchart of a process for moving a ground-based machine in a work area in accordance with an illustrative embodiment;

FIG. **15** is an illustration of a block diagram of an aircraft manufacturing and service method in accordance with an illustrative embodiment; and

FIG. **16** is an illustration of a block diagram of an aircraft in which an illustrative embodiment may be implemented.

DETAILED DESCRIPTION

The illustrative embodiments recognize and take into account that inductive power transfer systems used on assembly lines are set up using a fixed path. The fixed path is located along the assembly line. As a result, ground-based machines that use inductive power are unable to move away from the assembly line.

The illustrative embodiments recognize and take into account that the use of set paths such as those in assembly lines are not as useful when manufacturing is performed using stations rather than in assembly lines where the product moves continuously along the assembly line. The illustrative embodiments recognize and take into account that the lines used in inductive power transfer systems on assembly lines are laid out as tracks. The ground-based machines may move along those tracks and are unable to leave or move away from the tracks without losing power. The illustrative embodiments recognize and take into account that currently used ground-based machines that are powered by inductive power transfer systems require a precise alignment with the lines embedded in the ground.

The illustrative embodiments recognize and take into account that when manufacturing products in stations, ground-based machines may move in different directions within the work area. The illustrative embodiments recognize and take into account that the tracks used in inductive power transfer systems for assembly lines are not conducive to the type of movement used by ground-based machines manufacturing products in a work area.

Thus, the illustrative embodiments provide a method and apparatus for providing power to ground-based machines. In one illustrative embodiment, an apparatus includes a group of ground-based machines and a power system. The group of ground-based machines is configured to perform operations in a work area having a pattern of inductive power transfer lines physically associated with the ground in the work area. The power system is configured to provide power to the group of ground-based machines from the pattern of inductive power transfer lines such that the group of ground-based machines moves in the work area without following a path based on the power transfer lines.

With reference now to the figures, and in particular, with reference to FIG. **1**, an illustration of a block diagram of a manufacturing environment is depicted in accordance with an illustrative embodiment. In this illustrative example, manufacturing environment **100** is environment in which object **102** may be manufactured.

In this illustrative example, object **102** may take various forms. For example, object **102** may be selected from one of a mobile platform, a stationary platform, a land-based structure, an aquatic-based structure, and a space-based structure. More specifically, object **102** may be an aircraft, a surface ship, a tank, a personnel carrier, a train, a spacecraft, a space station, a satellite, a submarine, an automobile, a wing, a stabilizer, a fuselage section, an engine, an engine housing, and other suitable types of objects.

As depicted, ground-based machines **104** perform operations **106**. Ground-based machines **104** may take various forms. In these illustrative examples, ground-based machines **104** are mobile. Ground-based machines **104** may be, for example, a robotic arm, a crawler, a support platform, a portable drilling system, a portable tooling stand, an operator console, an autonomous navigating tool, a part storage container, a portable lifting jack, a portable metrology system, a portable measurement system, a composite layup machine, a portable forming tool, moveable power drop boxes, and other suitable types of machines.

The performance of operations **106** is part of manufacturing object **102**. Operations **106** may include assembling parts, drilling holes, inspecting parts, inspecting assemblies of parts, applying coatings, bonding parts, installing fasteners, vacuuming, sanding, welding, reworking, modifying parts, manufacturing operations, maintenance operations, and other suitable types of operations.

As depicted, a group of ground-based machines **104** is powered using wireless power transfer system **108**. As used herein, a "group of" when used with reference items means one or more items. For example, a group of ground-based machines **104** is one or more ground-based machines **104**. In the illustrative examples, the group of ground-based machines **104** may be some or all of ground-based machines **104**.

In this illustrative example, wireless power transfer system **108** may use inductive power transfer. When wireless power transfer system **108** uses inductive power transfer, the energy transferred is a form of energy transmission without the use of man-made conductors. Inductive power transfer may take a number of different forms. For example, inductive power transfer may be performed using direct induction, resonant magnetic induction, or other suitable types of induction.

In this illustrative example, wireless power transfer system **108** includes a number of different components. For example, wireless power transfer system **108** may include pattern **111** of inductive power transfer lines **112**, power source **114**, power system **116**, and other suitable types of components.

Pattern **111** of inductive power transfer lines **112** are power transfer lines physically associated with ground **118** in work area **120** in manufacturing environment **100**. When one component is "physically associated" with another component, the association is a physical association in the depicted examples. For example, a first component, inductive power transfer lines **112**, may be considered to be physically associated with a second component, ground **118**, by being secured to the second component, bonded to the second component, mounted to the second component, welded to the second component, fastened to the second component, and/or connected to the second component in some other suitable manner. The first component also may be connected to the second component using a third component. The first component may also be considered to be physically associated with the second component by being formed as part of the second component, extension of the second component, or both.

In these illustrative examples, pattern **111** of inductive power transfer lines **112** may be physically associated with ground **118** by being embedded in the ground or floor. In some illustrative examples, inductive power transfer lines **112** may be on the surface of the floor of ground **118**, partially in ground **118** and partially exposed on the surface of ground **118**, or physically associated in some other manner.

Pattern **111** of inductive power transfer lines **112** are configured to provide energy **122** inductively to the group of ground-based machines **104**. The configuration is such that the group of ground-based machines **104** may move within work area **120** without following a track or path based on inductive power transfer lines **112**. In other words, the group of ground-based machines **104** is able to move within work area **120** without following a path defined by inductive power transfer lines **112**.

As depicted, pattern **111** of inductive power transfer lines **112** may be configured such that the group of ground-based machines **104** may move between inductive power transfer lines **112** without losing an ability to obtain energy **122** between inductive power transfer lines **112**. For example, when moving from a first power transfer line to a second power transfer line in pattern **111** of inductive power transfer lines **112**, a ground-based machine in ground-based machines **104** may be able to obtain energy **122** from the second power transfer line before being unable to obtain a desired amount of energy **122** from the first inductive power transfer line.

Power source **114** may be one or more sources of energy. Power source **114** is connected to pattern **111** of inductive power transfer lines **112**. Power source **114** is configured to supply electrical energy to pattern **111** of inductive power transfer lines **112**. As depicted, power source **114** may take a number of different forms. For example, power source **114** may include at least one of an alternating current (AC) power outlet, a generator, or other suitable types of power sources.

As used herein, the phrase "at least one of", when used with a list of items, means different combinations of one or more of the listed items may be used and only one of each item in the list may be needed. For example, "at least one of item A, item B, or item C" may include, without limitation, item A, item A and item B, or item B. This example also may include item A, item B, and item C or item B and item C. Of course, any combinations of these items may be present. In other examples, "at least one of" may be, for example, without limitation, two of item A, one of item B, and ten of item C; four of item B and seven of item C; and other suitable combinations. The item may be a particular object, thing, or a category. In other words, at least one of means any combination of items and number of items may be used from the list but not all of the items in the list are required.

In this illustrative example, power system **116** is configured to obtain energy **122** for the group of ground-based machines **104** from pattern **111** of inductive power transfer lines **112**. Energy **122** is used to power the group of ground-based machines **104**. The manner in which energy **122** is obtained is such that the group of ground-based machines **104** may move in work area **120** without following a path based on the inductive power transfer lines in pattern **111** of inductive power transfer lines **112**. Of course, although the group of ground-based machines **104** are not required to follow the inductive power transfer lines, the group of ground-based machines **104** may follow the inductive power transfer lines.

As depicted, power system **116** may include a number of different components. For example, power system **116** may include inductive power transfer system **124**.

As depicted, inductive power transfer system **124** is physically associated with ground-based machines **104**. Inductive power transfer system **124** is configured to obtain energy **122** from pattern **111** of inductive power transfer lines **112**. In other words, inductive power transfer system **124** is configured to generate first energy **126** in energy **122**. First energy **126** is used by the group of ground-based machines **104** to perform operations **106**.

Additionally, power system **116** also may include energy storage system **128**. In this illustrative example, energy storage system **128** may be implemented using battery system **129**.

Energy storage system **128** may store energy **122** obtained from pattern **111** of inductive power transfer lines **112**. Energy **122** stored in energy storage system **128** may be used to provide energy **122** that is stored to power the group of ground-based machines **104**. In other words, energy storage system **128** may generate second energy **130** from energy **122** stored in energy storage system **128**. Energy storage system **128** generates second energy **130** to perform at least one of replacing first energy **126** when inductive power transfer system **124** is unable to generate first energy **126**, or supplementing first energy **126** when additional energy is needed.

As a result, an interruption in the delivery of energy **122** to ground-based machines **104** may be reduced or eliminated. The supply of energy, such as first energy **126** and second energy **130** for desired operation of ground-based machines **104** may occur without operator intervention.

In this manner, the group of ground-based machines **104** may perform operations **106** with more flexibility than available with currently used inductive power transfer systems designed for assembly line processing. For example, the group of ground-based machines **104** may move throughout work area **120** without following a path defined by a power transfer line. In particular, the group of ground-based machines **104** may move within work area **120** where pattern **111** of inductive power transfer lines **112** is present. Additionally, when energy storage system **128** is present, the group of ground-based machines **104** may also move within work area **120** and other locations where pattern **111** of inductive power transfer lines **112** is absent.

Turning now to FIG. **2**, an illustration of a block diagram of a ground-based machine is depicted in accordance with an illustrative embodiment. Ground-based machine **200** is an example of one implementation for a ground-based machine in ground-based machines **104** in FIG. **1**.

As depicted, ground-based machine **200** includes a number of different components. For example, ground-based machine **200** includes support structure **202**, movement system **204**, tool system **206**, sensor system **207**, controller **208**, a group of inductive power transfer units **214**, and a group of energy storage devices **216**.

Support structure **202** is a physical structure configured to provide support for other components within ground-based machine **200**. For example, support structure **202** may be at least one of a frame, a housing, or other suitable structures. Other components in ground-based machine **200** may be physically associated with support structure **202**.

In this illustrative example, movement system **204** is configured to move ground-based machine **200**. Movement system **204** may include a motor and movement elements. The movement elements may be selected from at least one of a wheel, a track, or other suitable types of movement elements that may provide mobility for ground-based machine **200**.

As depicted, tool system **206** includes one or more tools that may be used to perform operations **106** in FIG. **1**. Tool system **206** may include at least one of a fastener installer, a drill, a paint applicator, a sealant applicator, a part holder, an eddy current inspection system, an ultrasonic inspection system, an x-ray inspection system, a laser inspection system, a robot, an operator console, a light scanner, a welding head, a vacuum system, a composite material applicator, a tool storage unit, a consumables storage unit, an automated tool selector, a consumables selector, or other suitable types of tools.

In the illustrative example, sensor system **207** is configured to generate information about the environment around ground-based machine **200**. Sensor system **207** may include, for example, a camera, an ultrasonic sensor, an infrared sensor, a magnetic field sensor, a radio frequency identifier tag reader, and other suitable types of sensors.

For example, a magnetic field sensor in sensor system **207** may be used to identify whether an inductive power transfer line in inductive power transfer lines **112** is present. Additionally, the magnetic field sensor may be used to identify the location and orientation of other inductive power transfer lines in inductive power transfer lines **112**. In another illustrative example, the radio frequency identifier tag reader may be used to identify the location of radio frequency identifier tags in work area **120** in FIG. **1**. These radio frequency identifier tags may be used as markers to identify the locations of inductive power transfer lines **112**. In addition, the radio frequency identifier tags may include position information that may be used for navigation.

Controller **208** is a hardware system that may include software, firmware, or a combination of the two. When software is used, the operations performed by controller **208** may be implemented in program code configured to run on a processor unit in controller **208**. When firmware is used, the operations performed by controller **208** may be implemented in program code and data and stored in persistent memory to run on a processor unit.

The hardware in controller **208** may include circuits that operate to perform the operations. In the illustrative examples, the hardware may take the form of a circuit system, an integrated circuit, an application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device may be configured to perform the number of operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include, for example, a programmable logic array, a programmable array logic, a field programmable logic array, a field programmable gate array, and other suitable hardware devices. Additionally, the processes may be implemented in organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, the processes may be implemented as circuits in organic semiconductors.

Controller **208** is configured to control operation of ground-based machine **200**. Controller **208** may control the operation of at least one of movement system **204**, tool system **206**, or other components in ground-based machine **200**.

Controller **208** may have different levels of intelligence. For example, controller **208** may implement processes that include receiving input from an operator. In other illustrative examples, controller **208** may receive instructions from a computer system remote to ground-based machine **200**. The computer system may provide specific instructions such as where to move, how to position tools, when to operate tools, and other similar types of operations.

In other illustrative examples, controller **208** may have a higher level of intelligence. Controller **208** may perform tasks such as drilling holes in a pattern. Controller **208** may receive a task for drilling holes and an identification of the pattern. Controller **208** may then perform the task without additional input from a human operator or another computer system. With this level of intelligence, controller **208** may include an artificial intelligence system, a neural network, a fuzzy logic system, or some other suitable type of system.

The group of inductive power transfer units **214** is an example of components within inductive power transfer system **124** in FIG. **1**. As depicted, the group of inductive power transfer units **214** is configured to obtain energy **122** from pattern **111** of inductive power transfer lines **112**. In the illustrative example, the group of inductive power transfer units **214** obtains energy **122** from pattern **111** of inductive power transfer lines **112**. Energy **122** is used by the group of inductive power transfer units **214** to generate first energy **126**. Energy **122** may be electrical energy in the form of currents flowing through inductive power transfer lines **112**. In one illustrative example, magnetic fields generated through the flow of the currents may induce a flow of currents in the group of inductive power transfer units **214** to form first energy **126**.

First energy **126** may be generated at a desired level when moving from a first portion of pattern **111** of inductive power transfer lines **112** to a second portion of pattern **111** of inductive power transfer lines **112**. The portions may be different inductive power transfer lines within pattern **111** of inductive power transfer lines **112**, different sections of an inductive power transfer line in pattern **111** of inductive power transfer lines **112**, or both. For example, movement may be from a first inductive power transfer line to a second inductive power transfer line in inductive power transfer lines **112**.

For example, the group of inductive power transfer units **214** may have two inductive power transfer units. The two inductive power transfer units may be configured such that at least one of the two inductive power transfer units is able to obtain a desired amount of energy **122** to generate first energy **126** for use by components in ground-based machine **200** when moving from the first portion of pattern **111** of inductive power transfer lines **112** to a second portion of pattern **111** of inductive power transfer lines **112**.

For example, when moving from a first inductive power transfer line to a second inductive power transfer line, the first inductive power transfer unit obtains energy **122** from the first inductive power transfer line as ground-based machine **200** moves away from the first inductive power transfer line towards the second inductive power transfer line. The second inductive power transfer unit obtains energy **122** from the second inductive power transfer line prior to the first inductive power transfer unit being unable to obtain a desired amount of energy **122** from the first inductive power transfer line to generate first energy **126**.

Alternatively, a period of time may be present when energy **122** cannot be obtained by either the first inductive power transfer unit and the second inductive power transfer unit during movement from the first inductive power transfer line to the second inductive power transfer line. In this alternative example, the amount of time is small enough that ground-based machine **200** is able to operate at a desired level during that period of time.

In still another illustrative example, when a single inductive power transfer unit is present in the group of inductive power transfer units **214**, the single inductive power transfer unit may be moved or repositioned to obtain a desired level of first energy **126** during movement of ground-based machine **200** from the first inductive power transfer line to the second inductive power transfer line. The movement may be at least one of a change in location of one or more of the group of inductive power transfer units **214** or a change in orientation of one or more of the group of inductive power transfer units **214**.

In yet another illustrative example, the group of energy storage devices **216** is an example of components within energy storage system **128** in FIG. **1**. For example, the group of energy storage devices **216** may be selected from at least one of a battery, a fuel cell, a compressed air energy storage tank, or other suitable types of energy storage devices.

As depicted, the group of energy storage devices **216** is configured to provide second energy **130** from energy **122** stored in the group of energy storage devices **216**. In this manner, second energy **130** may be used to operate ground-based machine **200** when ground-based machine **200** moves from the first inductive power transfer line to the second inductive power transfer line and the group of inductive power transfer units **214** is unable to provide a desired level of first energy **126**. Of course, these different illustrative examples may apply to a first segment of an inductive power transfer line and a second segment of the same inductive power transfer line.

Additionally, when the group of inductive power transfer units **214** provides first energy **126**, the group of energy storage devices **216** may generate second energy **130** to supplement first energy **126**. For example, the operation of tool system **206** may require a higher level of energy than supplied by first energy **126**. Second energy **130** may be generated by the group of energy storage devices **216** such that the higher level of energy is available to tool system **206**.

The illustration of manufacturing environment **100** and the different components in manufacturing environment **100** in FIGS. **1** and **2** are not meant to imply physical or architectural limitations to the manner in which an illustrative embodiment may be implemented. Other components in addition to or in place of the ones illustrated may be used. Some components may be unnecessary. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be combined, divided, or combined and divided into different blocks when implemented in an illustrative embodiment.

For example, sensor system **207** may be omitted from ground-based machine **200** in FIG. **2**. Instead, an external sensor system may be used to generate information that may be sent to controller **208**. In other illustrative examples, another controller may send instructions to controller **208** using the information generated by the external sensor system. In other illustrative examples, ground-based machine **200** may omit the group of energy storage devices **216**.

Additionally, wireless power transfer system **108** may be used in other environments other than manufacturing environment **100** in FIG. **1**. For example, wireless power transfer system **108** may be used in a maintenance environment in which maintenance operations are performed on object **102**.

Additionally, the movement of ground-based machines **104** also may occur outside of work area **120** when energy storage system **128** is present in ground-based machines **104**. Energy storage system **128** may be used to provide second energy **130** to move ground-based machines **104** to locations for storage, maintenance, or other purposes.

Further, ground-based machines **104** may be heterogeneous or homogeneous in different implementations. For example, different ground-based machines in ground-based machines **104** may have different levels of intelligence. Additionally, some ground-based machines may be used to support structures and move structures. Other ground-based machines may be used to position structures, perform drilling operations, fastening operations, bonding operations, or other suitable operations. As another illustrative example, power source **114** may be a ground-based machine in ground-based machines **104**.

In another illustrative example, controller **208** in ground-based machine **200** may communicate with a master controller in work area **120**. The master controller may coordinate the operation of ground-based machine **200**.

With reference now to FIG. **3**, an illustration of a manufacturing environment is depicted in accordance with an illustrative embodiment. In this illustrative example, a plan view of manufacturing environment **300** is shown. Manufacturing environment **300** is an example of one implementation for manufacturing environment **100** in FIG. **1**. In this illustrative example, manufacturing environment **300** is an example of an environment in which ground-based machines **302** may operate to perform operations in manufacturing wing **304** for an aircraft in work area **306**.

As depicted, first group **308** of ground-based machines **302** is configured to perform operations in work area **306**. In particular, first group **308** of ground-based machines **302** is configured to hold wing **304**. In this illustrative example, first group **308** of ground-based machines **302** includes ground-based machine **312**, ground-based machine **314**, ground-based machine **316**, ground-based machine **318**, ground-based machine **320**, ground-based machine **322**, ground-based machine **324**, ground-based machine **326**, ground-based machine **328**, ground-based machine **330**, ground-based machine **332**, ground-based machine **334**, ground-based machine **336**, ground-based machine **338**, ground-based machine **340**, ground-based machine **342**, ground-based machine **344**, ground-based machine **346**, and ground-based machine **348**. As depicted, wing **304** is shown in phantom to illustrate ground-based machine **346** and ground-based machine **348** in the portion of first group **308** of ground-based machines **302** that are located under wing **304** in this view.

In particular, first group **308** of ground-based machines **302** may position and move wing **304** within work area **306**. Additionally, first group **308** of ground-based machines **302** also may move wing **304** to work area **306** and from work area **306** to another work area.

As depicted, second group **349** of ground-based machines **302** is configured to perform operations on wing **304**. Second group **349** of ground-based machines **302** includes ground-based machine **350**, ground-based machine **352**, ground-based machine **354**, ground-based machine **356**, and ground-based machine **358**. In these illustrative examples, second group **349** of ground-based machines **302** may perform operations to assemble parts to form wing **304**. Additionally, second group **349** of ground-based machines **302** also may apply coatings or other materials to wing **304**.

In these illustrative examples, operators **359** are human operators that perform operations in work area **306**. As depicted, operators **359** includes operator **360** and operator **362**. These operations may include at least one of assembling wing **304**, controlling operations of first group **308** of ground-based machines **302**, controlling operation of second group **349** of ground-based machines **302**, or other suitable operations.

As depicted, ground-based machines **302** in work area **306** derive power from inductive power system **364**. In this illustrative example, inductive power system **364** includes pattern of inductive power transfer lines **366**. As illustrated, pattern of inductive power transfer lines **366** are physically associated with ground **367** in work area **306**. As depicted, pattern of inductive power transfer lines **366** includes inductive power transfer line **368**, inductive power transfer line **370**, and inductive power transfer line **372**. Pattern of inductive power transfer lines **366** covers at a least a portion of work area **306**.

Inductive power system **364** also includes power source **374**. Power source **374** includes alternating current outlet **376**, alternating current outlet **378**, and alternating current outlet **380** in this particular example.

Pattern of inductive power transfer lines **366** has the configuration that allows for ground-based machines **302** to move within work area **306** without having to follow a particular track. Additionally, at least a portion of ground-based machines **302** are configured to store sufficient power to move between portions of pattern of inductive power transfer lines **366**. These portions may be different segments in an inductive power transfer line, different inductive power transfer lines, or some combination thereof.

For example, ground-based machine **332** may move in the direction of arrow **382** from inductive power transfer line **368** to inductive power transfer line **370**. During this movement, ground-based machine **332** moves across area **384** of ground **367** in work area **306** where an inductive power transfer line is absent.

As another illustrative example, ground-based machine **336** also may move in the direction of arrow **382** from first segment **386** of inductive power transfer line **370** to second segment **388** of inductive power transfer line **370**. This type of movement results in ground-based machine **336** moving across area **390** of ground **367** in work area **306** where an inductive power transfer line is absent.

In these illustrative examples, this type of movement of ground-based machine **332** and ground-based machine **336** between portions of pattern of inductive power transfer lines **366** may occur with these ground-based machines obtaining energy from the pattern of inductive power transfer lines **366** through a configuration of a group of inductive power transfer units in these ground-based machines. The portions may be, for example, first segment **386** and second segment **388**. The portions may be some other segment or part of pattern of inductive power transfer lines **366**.

In other illustrative examples, this type of movement may occur even though the configuration of the inductive power transfer units are unable to obtain a desired level of energy form the pattern of inductive power transfer lines **366** when moving between different portions of pattern of inductive power transfer lines **366**. Energy for the movement may be generated through a group of battery systems or other suitable types of energy storage systems in the ground-based machines.

Turning now to FIG. **4**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, a plan view of work area **400** with ground-based machine **402**, ground-based machine **404**, and ground-based machine **406** are shown. These ground-based machines are examples of an implementation for ground-based machine **200** in FIG. **2**. This view is a view looking upward from below ground **408** in work area **400**.

As illustrated, ground-based machine **402** includes inductive power transfer unit **410**, radio frequency identifier reader **412**, and magnetic detection sensor **414**. Ground-based machine **404** includes inductive power transfer unit **416**, radio frequency identifier reader **418**, and magnetic detection sensor **420**. Ground-based machine **406** includes inductive power transfer unit **422**, radio frequency identifier reader **424**, and magnetic detection sensor **426**.

The inductive power transfer units may be implemented using any currently available inductive power pickup units. The radio frequency identifier readers may be implemented using any currently available radio frequency identifier reader. In a similar fashion, the magnetic detection sensors also may be implemented using currently available magnetic detection sensors.

In this illustrative example, inductive power transfer unit **410** has a desired position relative to inductive power transfer line **428**. In this illustrative example, the position includes a location. The location may be described using two-dimensional or three-dimensional coordinates depending on the particular implementation. Additionally, the position also may include an orientation of inductive power transfer unit **410**.

In this illustrative example, the orientation of inductive power transfer unit **410** is the orientation of axis **430** extending through inductive power transfer unit **410** and ground-based machine **402** relative to inductive power transfer line **428**. In this particular example, this orientation provides a desired level of energy transfer from inductive power transfer line **428** to inductive power transfer unit **410**.

The orientation of inductive power transfer line **428** may be identified in a number of different ways. For example, magnetic detection sensor **414** may be used to detect a magnetic field generated by inductive power transfer line **428**. The information generated by magnetic detection sensor **414** may be used to identify the orientation of inductive power transfer line **428**.

As another illustrative example, radio frequency identifier reader **412** may be used to read radio frequency identifier tag **440**, radio frequency identifier tag **442**, radio frequency identifier tag **444**, radio frequency identifier tag **446**, radio frequency identifier tag **450**, radio frequency identifier tag **452**, radio frequency identifier tag **454**, and radio frequency identifier tag **456**. These radio frequency identifier tags may include information such as coordinates for a location in work area **400**, an indication of whether an inductive power transfer line is present at the coordinates, and other suitable information. The information from these radio frequency identifier tags may be used to identify the position of inductive power transfer line **428**.

As depicted, axis **458** for ground-based machine **404** is not aligned with inductive power transfer line **428**. However, the position of inductive power transfer unit **416** for ground-based machine **404** is changed to align axis **460** through inductive power transfer unit **416** with inductive power transfer line **428**.

In other words, inductive power transfer unit **416** may be moved on ground-based machine **404** to maintain a desired position of inductive power transfer unit **416** relative to inductive power transfer line **428** in the present position of ground-based machine **404**. For example, inductive power transfer unit **416** may be moved in the direction arrow **462** and may be rotated in the direction of arrow **464**. This type of movement of inductive power transfer unit **416** on ground-based machine **404** may be performed to obtain a desired position of inductive power transfer unit **416** relative to inductive power transfer line **428**. In these illustrative examples, this movement of inductive power transfer unit **416** may occur while ground-based machine **404** moves within work area **400**.

As depicted, ground-based machine **406** has a position in which inductive power transfer unit **422** is not positioned over inductive power transfer line **428**. In this example, a battery (not shown) in ground-based machine **406** may be used to provide energy to operate ground-based machine

406. The battery may provide energy until ground-based machine **406** returns to a position over inductive power transfer line **428** where energy can be obtained from inductive power transfer line **428** using inductive power transfer unit **422**.

In addition to providing for alignment of the inductive power transfer units, information generated by the radio frequency identifier readers and the magnetic detection sensors also may be used for navigation. In other words, the information generated by these sensors may be used to move ground-based machine **402**, ground-based machine **404**, and ground-based machine **406** to desired positions in work area **400**.

In this manner, the movement and location of ground-based machine **402**, ground-based machine **404**, and ground-based machine **406** in work area **400** is not constrained based on a path defined by inductive power transfer line **428**. In other words, a ground-based machine may move off of one segment of inductive power transfer line **428** to another segment of inductive power transfer line **428** and does not have to follow inductive power transfer line **428**. As a result, more flexibility is present in moving and positioning these ground-based machines when performing operations to manufacture an object.

Turning now to FIG. **5**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, ground-based machine **500** is shown. Ground-based machine **500** is an example of an implementation of ground-based machine **200** in FIG. **2**. The view depicted in FIG. **5** is a view looking upward at bottom side **501** of ground-based machine **500**.

As illustrated, ground-based machine **500** includes inductive power transfer unit **502**, radio frequency identifier reader **504**, magnetic detection sensor **506**, and elongate member **508**. These components are physically associated with ground-based machine **500**.

Elongate member **508** is configured to move inductive power transfer unit **502** relative to ground-based machine **500** with respect to an inductive power transfer line on a path as indicated by arrow **510** to a desired position to obtain a desired level of energy from an inductive power transfer line in this illustrative example. In this example, this movement aligns axis **511** through inductive power transfer unit **502** with the inductive power transfer line.

Elongate member **508** may move inductive power transfer unit **502** in the direction of arrow **512** and rotate inductive power transfer unit **502** in the direction of arrow **514**. In this manner, inductive power transfer unit **502** on ground-based machine **500** may be positioned in a desired position relative to the inductive power transfer line.

With reference now to FIG. **6**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, a side view of the bottom portion of ground-based machine **500** is seen in the direction of lines **6-6** in FIG. **5**.

As depicted, elongate member **508** is configured to rotate with respect to ground-based machine **500**. In this manner, elongate member **508** may align inductive power transfer unit **502** with the inductive power transfer line (not shown).

Turning now to FIG. **7**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, ground-based machine **700** is shown. Ground-based machine **700** is an example of an implementation of ground-based machine **200** in FIG. **2**. The view depicted in FIG. **7** is a view looking upward at bottom side **701** of ground-based machine **700**.

In this illustrative embodiment, ground-based machine **700** includes inductive power transfer unit **702**, radio frequency identifier reader **704**, magnetic detection sensor **706**, and elongate member **708**. Elongate member **708** is configured to move inductive power transfer unit **702** to align inductive power transfer unit **702** with an inductive power transfer line along arrow **710** in this illustrative example. This movement causes alignment of axis **711** through inductive power transfer unit **702** with the inductive power transfer line.

As depicted, inductive power transfer unit **702** is configured to move on elongate member **708** in the direction of arrow **712**. Additionally, inductive power transfer unit **702** is configured to rotate in the direction of arrow **714**. A desired position of inductive power transfer unit **702** relative to the inductive power transfer line may be obtained when this type of movement of inductive power transfer unit **702** is performed.

With reference now to FIG. **8**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, a front view of the bottom portion of ground-based machine **700** is seen in the direction of lines **8-8** in FIG. **7**.

In this illustrative example, inductive power transfer unit **702** moves in the direction of arrow **712** along elongate member **708**. Additionally, inductive power transfer unit **702** rotates with respect to elongate member **708**. This allows inductive power transfer unit **702** to align with the inductive power transfer line (not shown).

Turning now to FIG. **9**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, ground-based machine **900** is shown. Ground-based machine **900** is an example of an implementation of ground-based machine **200** FIG. **2**. In this illustrative example, a view of side **901** of ground-based machine **900** is shown.

In this illustrative example, ground-based machine **900** includes inductive power transfer unit **902**, radio frequency identifier reader **904**, magnetic detection sensor **906**, biasing system **908**, and array of ball bearings **910**. Biasing system **908** includes spring **912**, spring **914**, and spring **916**.

Biasing system **908** with spring **912**, spring **914**, and spring **916** is configured to apply force on inductive power transfer unit **902** in the direction of arrow **918**. In this manner, inductive power transfer unit **902** may be pressed towards ground **920** such that inductive power transfer unit **902** maintains a constant distance to ground **920** as ground-based machine **900** moves along an inductive power transfer line, such as inductive power transfer line **428** in FIG. **4**.

Array of ball bearings **910** allows inductive power transfer unit **902** to move freely with ground-based machine **900** on ground **920** as ground-based machine **900** moves along an inductive power transfer line. Additionally, array of ball bearings **910** position inductive power transfer unit **902** substantially parallel to ground **920** as force in the direction of arrow **918** is applied to inductive power transfer unit **902**. In this manner, inductive power transfer unit **902** remains substantially parallel to ground **920** as inductive power transfer unit **902** on ground-based machine **900** moves on ground **920** along an inductive power transfer line.

With reference now to FIG. **10**, an illustration of a ground-based machine with an inductive power transfer unit is depicted in accordance with an illustrative embodiment. In this illustrative example, a view of the bottom portion of ground-based machine **900** is seen in the direction of lines **10-10** in FIG. **9**.

In this illustrative example, array of ball bearings **910** is shown. Array of ball bearings **910** is configured to apply a force on inductive power transfer unit **902** such that inductive power transfer unit **902** may remain at a constant distance to the ground when inductive power transfer unit **902** is aligned with an inductive power transfer line on a path as indicated by arrow **1000** along axis **1002**.

Turning now to FIG. **11**, an illustration of a ground-based machine with a sensor system is depicted in accordance with an illustrative embodiment. In this illustrative embodiment, ground-based machine **1100** is shown. Ground-based machine **1100** is an example of an implementation of ground-based machine **200** in FIG. **2**. The view depicted in FIG. **11** is a view looking upward at bottom side **1101** of ground-based machine **1100**.

In this illustrative example, ground-based machine **1100** includes a number of different components. As depicted, ground-based machine **1100** includes inductive power transfer unit **1102**, radio frequency identifier reader **1104**, and magnetic detection sensor system **1106**.

Magnetic detection sensor system **1106** is configured to provide information about the position of ground-based machine **1100**. In particular, magnetic detection sensor system **1106** may provide information about the position of ground-based machine **1100** relative to inductive power transfer line **1107**. In this illustrative example, magnetic detection sensor system **1106** includes array of magnetic sensors **1108**.

Each magnetic sensor in array of magnetic sensors **1108** is configured to measure the strength of the magnetic field created by inductive power transfer line **1107**. With this information, the distance to each magnetic sensor in array of magnetic sensors **1108** may be calculated from the measured strength of the magnetic field at any particular array. Distance **1110** from inductive power transfer line **1107** to sensor reference frame array **1112** is determined in this manner. Distance **1110** is used to determine the distance of ground-based machine **1100** from inductive power transfer line **1107**.

Additionally, array of magnetic sensors **1108** may be used to calculate angle **1114** at which ground-based machine **1100** lies with respect to inductive power transfer line **1107**. The difference in the strength of the magnetic field detected by each magnetic sensor in array of magnetic sensors **1108** may be used to calculate angle **1114**.

As depicted, array of magnetic sensors **1108** in magnetic detection sensor system **1106** forms reference line **1116** on ground-based machine **1100**. When the magnetic sensors in array of magnetic sensors **1108** measure the strength of the magnetic field created by inductive power transfer line **1107**, angle **1114** between reference line **1116** and inductive power transfer line **1107** may be determined. As a result, magnetic detection sensor system **1106** may be used to identify an orientation of ground-based machine **1100** relative to inductive power transfer line **1107**.

In this illustrative example, radio frequency identifier reader **1104** is configured to measure distance **1120** between radio frequency identifier tag **1122** and radio frequency identifier reader **1104**. Distance **1120** may be used to determine the location of ground-based machine **1100** along inductive power transfer line **1107**.

This feature of identifying the position, orientation, or both for ground-based machine **1100** is in contrast to currently used ground-based machines with inductive power transfer lines. Currently used ground-based machines follow the inductive power transfer line when moving. As a result, the position and orientation of the ground-based machine is unnecessary with respect to moving the ground-based machine.

In contrast, a ground-based machine in an illustrative example may move from one inductive power transfer line to another inductive power transfer line within a pattern of inductive power transfer lines. In addition, the ground-based machines may move from one portion of an inductive power transfer line to another portion of the same inductive power transfer line in the pattern of the inductive power transfer lines rather than following the inductive power transfer line. This type of movement is aided through the identification of the orientation, location, or both for the ground-based machine.

The illustration of ground-based machines in FIGS. **3-11** are only presented as examples of implementations for ground-based machines **104** in FIG. **1**. Further, the illustration of wing **304** in FIG. **3** is also intended as an example of one implementation for object **102** in FIG. **1**. In other illustrative examples, object **102** may be a fuselage, a wing panel, an engine housing, an automotive assembly, a ship hull, or other suitable types of objects. Further, in some illustrative examples, human operators such as operator **360** and operator **362** may be absent from work area **306**. In other words, the operations performed on wing **304** may be entirely automated without needing operators in work area **306**.

The different components shown in FIGS. **3-11** may be combined with components in FIGS. **1** and **2**, used with components in FIGS. **1** and **2**, or a combination of the two. Additionally, some of the components in FIGS. **3-11** may be illustrative examples of how components shown in block form in FIGS. **1** and **2** can be implemented as physical structures.

With reference now to FIG. **12**, an illustration of a flowchart of a process for distributing energy to ground-based machines is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **12** may be implemented in manufacturing environment **100** in FIG. **1**. In other illustrative examples, this process may be implemented in a maintenance environment.

The process begins by supplying energy to a group of ground-based machines through a pattern of inductive power transfer lines physically associated with a ground in a work area (operation **1200**). The ground-based machines then perform operations within the work area using the energy obtained from the pattern of inductive power transfer lines (operation **1202**), with the process terminating thereafter. The group of ground-based machines may move in the work area without following a path based on the inductive power transfer lines.

Turning now to FIG. **13**, an illustration of a flowchart of a process for transferring power from an inductive power transfer line to a ground-based machine is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **13** may be implemented in ground-based machine **200** in FIG. **2**. In particular, the different operations may be used to position an inductive power transfer unit in a group of inductive power transfer units in a ground-based machine. This positioning may be used to provide a desired level of energy transferred from the inductive power transfer line to the ground-based machine.

The process begins by identifying a position of an inductive power transfer line (operation **1300**). The position of the inductive power transfer line may be identified using sensor system **207** in ground-based machine **200**. The position may include X coordinates and Y coordinates. Additionally, the positioning also may include an orientation of the inductive power transfer line. The sensor system may include at least one of a magnetic field sensor, a radio frequency identifier reader, or some other suitable type of sensor.

A determination is made as to whether the current position of the inductive power transfer unit generates a desired level of energy from the inductive power transfer line (operation **1302**). The inductive power transfer unit may include a sensor onboard that gives an indication of the output to the controller quantifying the power level attained. This indication may be, for example, binary value indicating whether the power transfer is good or bad. In another example, the indication may indicate the percent efficiency of power transfer.

If the position of the inductive power transfer unit does not generate a desired level of energy from the inductive power transfer line, the process identifies a new position for the inductive power transfer unit (operation **1304**). The process then moves the inductive power transfer unit to the new position (operation **1306**), with the process then returning to operation **1300**.

With reference again to operation **1302**, if the inductive power transfer unit generates a desired level of energy, the process also returns to operation **1300**.

Turning now to FIG. **14**, an illustration of a flowchart of a process for moving a ground-based machine in a work area is depicted in accordance with an illustrative embodiment. The process illustrated in FIG. **14** may be implemented using ground-based machine **200** in FIG. **2**. In this illustrative example, the process may identify movement for a ground-based machine to move the ground-based machine towards an inductive power transfer line. This process may be used when moving a ground-based machine from one portion of a pattern of inductive power transfer lines to another portion of the pattern of inductive power transfer lines.

The process begins by identifying an initial position of a ground-based machine (operation **1400**). This initial position may be entered or programmed into the ground-based machine. The process then identifies a movement of the ground-based machine (operation **1402**). This movement may be identified from movement of wheels, tracks, or other locomotion elements on the ground-based machine. With this movement and the initial position of the ground-based machine, a current location of the ground-based machine may be identified.

The process then generates information from a magnetic field sensor (operation **1404**). The magnetic field sensor may be used to identify a distance and direction to an inductive power transfer line generating the magnetic field.

The process then identifies the movement for the ground-based machine based on the current location of the ground-based machine and the distance and direction to the inductive power transfer line (operation **1406**). The process then moves the ground-based machine based on the identified movement (operation **1408**), with the process terminating thereafter.

The flowcharts and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatuses and methods in an illustrative embodiment. In this regard, each block in the flowcharts or block diagrams may represent a module, a segment, a function, and/or a portion of an operation or step. For example, one or more of the blocks may be implemented as program code, in hardware, or a combination of the program code and hardware. When implemented in hardware, the hardware may, for example, take the form of integrated circuits that are manufactured or configured to perform one or more operations in the flowcharts or block diagrams. When implemented as a combination of program code and hardware, the implementation may take the form of firmware.

In some alternative implementations of an illustrative embodiment, the function or functions noted in the blocks may occur out of the order noted in the figures. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be performed in the reverse order, depending upon the functionality involved. Also, other blocks may be added in addition to the illustrated blocks in a flowchart or block diagram.

Illustrative embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **1500** as shown in FIG. **15** and aircraft **1600** as shown in FIG. **16**. Turning first to FIG. **15**, an illustration of an aircraft manufacturing and service method is depicted in accordance with an illustrative embodiment. During pre-production, aircraft manufacturing and service method **1500** may include specification and design **1502** of aircraft **1600** in FIG. **16** and material procurement **1504**.

During production, component and subassembly manufacturing **1506** and system integration **1508** of aircraft **1600** in FIG. **16** takes place. Thereafter, aircraft **1600** in FIG. **16** may go through certification and delivery **1510** in order to be placed in service **1512**. While in service **1512** by a customer, aircraft **1600** in FIG. **16** is scheduled for routine maintenance and service **1514**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **1500** may be performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, a leasing company, a military entity, a service organization, and so on.

With reference now to FIG. **16**, an illustration of an aircraft is depicted in which an illustrative embodiment may be implemented. In this example, aircraft **1600** is produced by aircraft manufacturing and service method **1500** in FIG. **15** and may include airframe **1602** with plurality of systems **1604** and interior **1606**. Examples of systems **1604** include one or more of propulsion system **1608**, electrical system **1610**, hydraulic system **1612**, and environmental system **1614**. Any number of other systems may be included. Although an aerospace example is shown, different illustrative embodiments may be applied to other industries, such as the automotive industry.

Apparatuses and methods embodied herein may be employed during at least one of the stages of aircraft manufacturing and service method **1500** in FIG. **15**.

In one illustrative example, components or subassemblies produced in component and subassembly manufacturing **1506** in FIG. **15** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **1600** is in service **1512** in FIG. **15**. As yet another example, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly manufacturing **1506** and system integration **1508** in FIG. **15**. One or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during maintenance and service **1514** in FIG. **15**. The use of a number of the different illustrative embodiments may substantially expedite the assembly of and/or reduce the cost of aircraft **1600**.

Thus, the illustrative embodiments provide a method and apparatus for providing energy to ground-based machines. A pattern of inductive power transfer lines are located in a work area in which the ground-based machines perform operations. This pattern is configured such that the ground-based machines may move within the work area without being required to follow a path defined by the inductive power transfer lines.

In the illustrative examples, a ground-based machine is able to move a distance from a first inductive power transfer line to a second inductive power transfer line in the inductive power transfer lines and maintain a desired level of energy for performing operations such as the movement of the ground-based machine or other suitable operations.

In this manner, changes in the flow between work areas, the flow within work areas, or both may be made more quickly using an illustrative embodiment. These changes are more easily made as compared to currently used inductive power transfer systems because the movement of the ground-based machines in the work area is not based on paths defined using the inductive power transfer lines. Instead, ground-based machines may move within the work area without following a path defined by the inductive power transfer lines. As a result, redesigning the flow of how tasks or operations are performed in a work area does not require changing the pattern of the inductive power transfer lines within the work area.

In this manner, a more flexible manufacturing environment may be implemented using an illustrative embodiment. In this manner, changes to the manufacturing of objects such as aircraft over the lifespan of the aircraft may be implemented more easily and with less cost. Additionally, reconfiguration of a manufacturing environment may be performed more easily because movement of ground-based machines does not rely on a particular path of inductive power transfer lines.

The description of the different illustrative embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different features as compared to other illustrative embodiments. The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

What is claimed is:

1. An apparatus comprising:

a pattern of inductive power transfer lines physically associated with a ground in a work area; and

a ground-based machine configured to move in the work area and comprising an inductive power transfer system on the ground-based machine and configured to obtain energy for the ground-based machine from the pattern of the inductive power transfer lines, wherein the inductive power transfer system comprises an inductive power transfer unit that is moveable on the ground-based machine with respect to the ground-based machine.

2. The apparatus of claim **1**, wherein the inductive power transfer system further comprises:

an energy storage system configured to store the energy for the ground-based machine.

3. The apparatus of claim **1**, wherein the inductive power transfer system is configured to obtain energy for the ground-based machine from the pattern of the inductive power transfer lines when the ground-based machine moves without following a path corresponding to the pattern of inductive power transfer lines.

4. The apparatus of claim **2**, wherein the inductive power transfer system generates first energy and the energy storage system generates second energy, wherein the energy storage system generates the second energy to perform at least one of replacing the first energy when the inductive power transfer system is unable to generate the first energy or supplementing the first energy when additional energy is needed.

5. The apparatus of claim **1**, wherein a tool system on the ground-based machine obtains energy from at least one of the inductive power transfer system or an energy storage system.

6. The apparatus of claim **1** further comprising:

a sensor system configured to identify a position of an inductive power transfer line in the pattern of the inductive power transfer lines.

7. The apparatus of claim **6**, wherein the inductive power transfer system

is configured to increase the energy obtained for the ground-based machine from the pattern of the inductive power transfer lines from a location of the position of the inductive power transfer line.

8. The apparatus of claim **6** further comprising:

a controller configured to control movement of the ground-based machine from positions of the inductive power transfer line detected by the sensor system.

9. The apparatus of claim **1**, wherein the

inductive power transfer unit is configured to move to different positions on the ground-based machine relative to the ground-based machine to maintain a distance of the inductive power transfer unit on the ground-based machine with respect to an inductive power transfer line in the pattern of the inductive power transfer lines when the ground-based machine is moving away from or toward the inductive power transfer line.

10. The apparatus of claim **1**, wherein the inductive power transfer unit is configured to move to different orientations on the ground-based machine relative to the ground-based machine to maintain alignment of the inductive power transfer unit on the ground-based machine with respect to an inductive power transfer line in the pattern of the inductive power transfer lines when the ground-based machine is moving to change an orientation of the ground-based machine with respect to the inductive power transfer line.

11. A wireless power transfer system comprising:

a power source configured to generate energy;

a pattern of inductive power transfer lines physically associated with a ground in a work area and connected to the power source; and

a power system configured to obtain the energy for a ground-based machine from the pattern of the inductive power transfer lines, wherein:

the power system comprises an inductive power transfer unit that is moveable on the ground-based machine with respect to the ground-based machine; and

the power system and the pattern of inductive power transfer lines are configured such that the power system obtains energy for the ground-based machine without the ground-based machine being aligned parallel to the inductive power transfer lines.

12. The wireless power transfer system of claim **11** further comprising:

the ground-based machine configured to perform operations in the work area.

13. The wireless power transfer system of claim **11**, wherein the power system comprises:

an inductive power transfer system configured to obtain the energy from the pattern of inductive power transfer lines.

14. The wireless power transfer system of claim **13**, wherein the power system further comprises:

an energy storage system configured to store the energy for the ground-based machine.

15. The wireless power transfer system of claim **12**, wherein the operations are selected from at least one of manufacturing operations or maintenance operations.

16. The wireless power transfer system of claim **11**, wherein the power system comprises:

an inductive power transfer unit physically associated with the ground-based machine, wherein the inductive power transfer unit is configured to move relative to the ground-based machine with respect to an inductive power transfer line in the pattern of inductive power transfer lines to a desired position to obtain a desired level of energy from the inductive power transfer line.

17. A method for distributing energy to a ground-based machine the method comprising:

supplying the energy to the ground-based machine through a pattern of inductive power transfer lines physically associated with a ground in a work area;

moving an inductive power transfer unit physically associated with the ground-based machine relative to the ground-based machine; and

performing operations with the ground-based machine in the work area, wherein the ground-based machine obtains energy without being aligned parallel to the pattern of inductive power transfer lines.

18. The method of claim **17**,

wherein the inductive power transfer unit is configured to move relative to the ground-based machine with respect to an inductive power transfer line in the pattern of the inductive power transfer lines to a desired position to obtain a desired level of energy from the inductive power transfer line.

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